Boedeker.com

DuPont™ Teflon® PTFE Specifications

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TECHNICAL DESCRIPTION

Discovered in 1938 by Dr. Roy J. Plunkett of the DuPont Company, Teflon® is a fluorocarbon-based polymer. PolyTetraFluoroEthylene is commonly abbreviated PTFE, and the Teflon® brand of PTFE is manufactured only by DuPont™. The fluoroplastic family offers plastics with high chemical resistance, low and high temperature capability, resistance to weathering, low friction, electrical and thermal insulation, and "slipperiness".

(see also Generic PTFE and Teflon® FEP & PFA Specifications)

GENERAL PROPERTIES

Mechanical properties of Teflon® are low compared to other plastics, but its properties remain at a useful level over a wide temperature range of of -100°F to +400°F (-73°C to 204°C). Mechanical properties are often enhanced by adding fillers (see paragraph below). It has excellent thermal and electrical insulation properties and a low coefficient of friction. PTFE is very dense and cannot be melt processed -- it must be compressed and sintered to form useful shapes.

FILLED GRADES

PTFE's mechanical properties can be enhanced by adding fillers such as glass fibers, carbon, graphite, molybdenum disulphide, and bronze. Generally, filled PTFE's maintain their excellent chemical and high temperature characteristics, while fillers improve mechanical strength, stability, and wear resistance.

The properties of 25% glass-filled and 25% carbon-filled PTFE grades are shown below for comparison purposes. There are literally dozens of different filled PTFE products and grades -- too many to be listed here. Please contact Boedeker Plastics for more information about other filled PTFE products for your application.

(see also Semitron ESd 500 Static-Dissipative PTFE | Fluorosint Filled PTFE | Rulon Filled PTFE Specifications)

TYPICAL PROPERTIES of TEFLON® PTFE

ASTM or UL test	Property	PTFE (unfilled)	PTFE (25% glass filled)	PTFE (25% carbon filled)
	PHYSICAL			
D792	Density (lb/in³) (g/cm³)	0.078 2.16	0.081 2.25	0.075 2.08
D570	Water Absorption, 24 hrs (%)	< 0.01	0.02	0.05
	MECHANICAL			
D638	Tensile Strength (psi)	3,900	2,100	1,900
D638	Tensile Modulus (psi)	80,000	-	-
D638	Tensile Elongation at Break (%)	300	270	75
D790	Flexural Strength (psi)	No break	1,950	2,300
D790	Flexural Modulus (psi)	72,000	190,000	160,000
D695	Compressive Strength (psi)	3,500	1,000	1,700
D695	Compressive Modulus (psi)	70,000	110,000	87,000
D785	Hardness, Shore D	D50	D60	D62
D256	IZOD Notched Impact (ft-lb/in)	3.5	-	-
	THERMAL			
D696	Coefficient of Linear Thermal Expansion ($x\ 10^{-5}$ in./in./°F)	7.5	6.4	6.0
D648	Heat Deflection Temp (°F / °C) at 264 psi	132 / 55	150 / 65	150 / 65
D3418	Melting Temp (°F / °C)	635 / 335	635 / 335	635 / 335
-	Max Operating Temp (°F / °C)	500 / 260	500 / 260	500 / 260
C177	Thermal Conductivity (BTU-in/ft²-hr-°F) ($x\ 10^{-4}$ cal/cm-sec-°C)	1.70 5.86	3.1 10.6	4.5 15.5
UL94	Flammability Rating	V-O	V-O	V-O
	ELECTRICAL			
D149	Dielectric Strength (V/mil) short time, 1/8" thick	285	-	-
D150	Dielectric Constant at 1 MHz	2.1	2.4	-
D150	Dissipation Factor at 1 MHz	< 0.0002	0.05	-
D257	Volume Resistivity (ohm-cm)at 50% RH	$> 10^{18}$	$> 10^{15}$	10^{4}

NOTE: The information contained herein are typical values intended for reference and comparison purposes only. They should NOT be used as a basis for design specifications or quality control. Contact us for manufacturers' complete material property datasheets
All values at 73°F (23°C) unless otherwise noted.

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thermoset laminate properties

Acculam™

Properties	NEMA grade reinforcement~ resin binder	FR4 glass~ epoxies	FR5 glass~ epoxy HT	G9 glass~ melamine	G7 glass~ silicone	GP0 1 glassmat~ polyester	GP03 glassmat~ polyester	X paper pheno
Tensile Strength								
	lengthwise, PSI	40,000	40,000	37,000	23,000	12,000	11,000	20,00
	crosswise, PSI	35,000	35,000	30,000	18,000	-	-	16,00
Compressive Strength								
	flatwise, PSI	60,000	60,000	70,000	45,000	40,000	30,000	36,00
	edgewise, PSI	35,000	35,000	25,000	14,000	-	-	19,00
Flexural Strength								
	lengthwise, PSI	55,000	55,000	55,000	23,000	23,000	20,000	25,00
	crosswise, PSI	45,000	45,000	35,000	20,000	-	-	22,00

Properties	NEMA grade reinforcement~ resin binder	FR4 glass~ epoxies	FR5 glass~ epoxy HT	G9 glass~ melamine	G7 glass~ silicone	GP0 1 glassmat~ polyester	GP03 glassmat~ polyester	X paper pheno
Modulus of Elasticity in flex								
	lengthwise, PSI x 10^6	2.7	2.7	2.5	1.4	-	-	1.8
	crosswise, PSI x 10^6	2.2	2.2	2.0	1.2	-	-	1.3
Shear Strength, PSI		19,000	19,000	20,000	17,000	-	-	12,00
IZOD Impact								
	flatwise, ft lb per inch of notch	7	7	12	8.5	-	-	4

edgewise, ft lb per inch of notch		5.5	5.5	8	7.5	-	-	0.5
Rockwell Hardness M scale		110	110	120	100	-	-	110
Specific Gravity		1.82	1.82	1.9	1.68	1.8	1.85	1.36
Coefficient of Thermal Expansion								
cm/cm/ deg C x 10^{-5}		.9	.9	1	1	-	-	6
Properties	NEMA **grade** reinforcement~ resin binder	**FR4** glass~ epoxies	**FR5** glass~ epoxy HT	**G9** glass~ melamine	**G7** glass~ silicone	**GP0 1** glassmat~ polyester	**GP03** glassmat~ polyester	**X** paper pheno
Water Absorption								
.062" thick, % per 24 hrs		0.25	0.25	0.8	0.3	0.35	0.4	6
.125" thick, % per 24 hrs		0.15	0.15	0.7	0.2	-	-	3.3
.500" thick, % per 24 hrs		0.10	0.10	0.4	0.15	-	-	1.1
Dielectric Strength, volt/mil								
perpendicular to laminations; short								
.062" thick		500	500	400	400	370	400	700
.125" thick		400	400	350	350	-	-	500
Dissipation Factor								
condition A, 1 megacycle		0.025	0.025	0.017	0.003	-	-	0.06
Dielectric Constant								
condition A, 1 megacycle		5.2	5.2	7.12	4.2	-	-	6
Properties	NEMA **grade** reinforcement~ resin binder	**FR4** glass~ epoxies	**FR5** glass~ epoxy HT	**G9** glass~ melamine	**G7** glass~ silicone	**GP0 1** glassmat~ polyester	**GP03** glassmat~ polyester	**X** paper pheno
Insulation Resistance								
Condition: 96 hours at 90% relative humidity (in mega ohms)		200,000	200,000	10,000	200,000	-	-	-
Flame Resistance								

Underwriter Labs, Classification		94V-0	94V-0	94V-0	94V-0	94HB	94V-0	94H
Bond Strength, in lbs		2,000	1,600	1,700	650	-	-	700
Max Continuous Operating Temperature								
Approximate degrees F		285	300	285	465	265	265	285
Properties	NEMA **grade** reinforcement~ resin binder	**FR4** glass~ epoxies	**FR5** glass~ epoxy HT	**G9** glass~ melamine	**G7** glass~ silicone	**GP0 1** glassmat~ polyester	**GP03** glassmat~ polyester	**X** paper pheno
Acculam tradenames		Epoxyglas	EpoxyglasHT	Melaglas	Siliglas	Polymat-1	Polymat-3	Phenolk
Acculam grades		G10,FR4	G11,FR5	G5,G9	G7	GP0-1	GPO-3	X
sheet mil spec: Mil-1-24768 / _ _		27	28	1	17	4	6	12
types		GEE-F	GEB-F *	GME	GSG	GPO1	GPO3	PBM

You Know It's Right... When It's Accurate

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Coefficient of thermal expansion

From Wikipedia, the free encyclopedia

Material Properties	
Specific heat	$c = \frac{T}{N}\left(\frac{\partial S}{\partial T}\right)$
Compressibility	$\beta = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)$
Thermal expansion	$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)$

During heat transfer, the energy that is stored in the intermolecular bonds between atoms changes. When the stored energy increases, so does the length of the molecular bond. As a result, solids typically* expand in response to heating and contract on cooling; this response to temperature change is expressed as its coefficient of thermal expansion:

The **coefficient of thermal expansion** is used in two ways:

- as a *volumetric* thermal expansion coefficient
- as a *linear* thermal expansion coefficient

These characteristics are closely related. The volumetric thermal expansion coefficient can be measured for all substances of condensed matter (liquids and solid state). The linear thermal expansion can only be measured in the solid state and is common in engineering applications.

* Some substances have a negative expansion coefficient, and will expand when cooled (e.g. freezing water).

Contents

Volumetric thermal expansion coefficient

The **volumetric thermal expansion coefficient** (sometimes simply **thermal expansion coefficient)** is a thermodynamic property of a substance given by (Incropera, 2001 p537)

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_P$$

where T is the temperature, V is the volume, ρ is the density, derivatives are taken at constant pressure P; β measures the fractional change in density as temperature increases at constant pressure.

Proof:

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P = \frac{\rho}{m}\left(\frac{\partial V}{\partial \rho}\right)_P\left(\frac{\partial \rho}{\partial T}\right)_P = \frac{\rho}{m}\left(-\frac{m}{\rho^2}\right)\left(\frac{\partial \rho}{\partial T}\right)_P = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_P$$

where m is the mass.

The expansion of a crystalline material occurs only when the force field of the crystal deviates from a perfect quadratic. If the force field is perfectly parabolic, no expansion will occur.

Linear thermal expansion coefficient

The **linear thermal expansion coefficient** relates the change in temperature to the change in a material's linear dimensions. It is the fractional change in length of a bar per degree of temperature change.

$$\alpha = \frac{1}{L}\frac{\partial L}{\partial T}$$

The expansion and contraction of material must be considered when designing large structures, when using tape or chain to measure distances for land surveys, when designing molds for casting hot material, and in other engineering applications when large changes in dimension due to temperature are expected. Some values for common materials, given in parts per million per Celsius degree: (NOTE: This can also be in kelvins as the changes in temperature are a 1:1 ratio)

coefficient of linear thermal expansion α	
material	**α in 10^{-6}/K at 20 °C**
Mercury	60
BCB	42
Lead	29
Aluminum	23
Brass	19
Stainless steel	17.3
Copper	17
Gold	14
Nickel	13
Concrete	12
Iron or Steel	12
Carbon steel	10.8
Platinum	9
Glass	8.5
GaAs	5.8
Indium Phosphide	4.6
Tungsten	4.5
Glass, Pyrex	3.3
Silicon	3
Diamond	1
Quartz, fused	0.59

For exactly isotropic materials, the linear thermal expansion coefficient is very closely approximated as one-third the volumetric coefficient.

$$\beta \cong 3\alpha$$

Proof:

$$\beta = \frac{1}{V}\frac{\partial V}{\partial T} = \frac{1}{L^3}\frac{\partial L^3}{\partial T} = \frac{1}{L^3}\left(\frac{\partial L^3}{\partial L}\cdot\frac{\partial L}{\partial T}\right) \cong \frac{1}{L^3}\left(3L^2\frac{\partial L}{\partial T}\right) = 3\cdot\frac{1}{L}\frac{\partial L}{\partial T} = 3\alpha$$

This ratio arises because volume is composed of three mutually orthogonal directions. Thus, in an isotropic material, one-third of the volumetric expansion is in a single axis (a very close approximation for small differential changes). Note that the partial derivative of volume with respect to length as shown in the above equation is exact, however, in practice it is important to note that the differential change in volume is only valid for small changes in volume (ie the expression is not linear). As the change in temperature increases, and as the value for the linear coefficient of thermal expansion increases, the error in this formula also increases. For non-negligible changes in volume:

$$(L+\Delta L)^3 = L^3 + 3L^2\Delta L + 3L\Delta L^2 + \Delta L^3$$

Note that this equation contains the main term, $3L^2$, but also shows a secondary term that scales as $3L\Delta L^2 = 3L^3\alpha^2\Delta T^2$, which shows that a large change in temperature can overshadow a small value for the linear coefficient of thermal expansion. Although the coefficient of linear thermal expansion can be quite small, when combined with a large change in temperature the differential change in length can become large enough that this factor needs to be considered. The last term, ΔL^3 is vanishingly small, and is almost universally ignored. In anisotropic materials the total volumetric expansion is distributed unequally among the three axes.

Applications

For applications using the thermal expansion property, see bi-metal and mercury thermometer

Thermal expansion is also used in mechanical applications to fit parts over one another, e.g. a bushing can be fitted over a shaft by making its inner diameter slightly smaller than the diameter of the shaft, then heating it until it fits over the shaft, and allowing it to cool after it has been pushed over the shaft, thus achieving a 'shrink fit'

There exist some alloys with a very small CTE, used in applications that demand very small changes in physical dimension over a range of temperatures. One of these is Invar 36, with a coefficient in the 0.0000016 range. These alloys are useful in aerospace applications where wide temperature swings may occur.

External links

- Free database of engineering properties for over 50,000 materials (http://www.matweb.com/)
- Clemson University Physics Lab: Linear Thermal Expansion (http://phoenix.phys.clemson.edu/labs/223/expansion/index.html)
- USA NIST Website - Temperature and Dimensional Measurement workshop (http://emtoolbox.nist.gov/Temperature/Slide1.asp#Slide1)

References

- Incropera, Frank P.; David P. DeWitt (August 9 2001). *Fundamentals of Heat and Mass Transfer*, 5th Edition, Wiley. ISBN 0-471-38650-2.

Categories: Heat | Physical quantity